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<u>MEMORANDUM</u>

SUBJECT: Respiratory Deposition and Absorption of Lead Particles

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     This memo summarizes procedures currently used to estimate respiratory
deposition, and subsequent absorption into the bloodstream, of inhaled
lead particles that occur in different atmospheres. In our ongoing
review of the lead national ambient air quality standard (NAAQS), a
multi-media lead exposure model will assess possible health risk impacts
associated with alternative standards. The model estimates total daily
lead uptake, or lead absorbed into the bloodstream, from all sources via
the lungs and gut beginning at birth. Although the largest contribution
to lead exposure, especially among young children, is from the diet and
ingestion (even inadvertant) of lead-contaminated soil and dust, inhalation
accounts for some lead uptake. It is possible to quantify this latter
exposure route using available data on particle size distributions,
respiratory condition (e.g., tidal volume), particle deposition patterns
as a function of age, and lead particle absorption in the lung. However,
accurate information relevant to conditions of most concern, namely
exposure to young children in areas near stationary industrial sources,
is sparse and our resulting estimates will be uncertain. The
following discussion identifies the available data and the assumptions
used in deriving these estimates as well as the associated uncertainties.
Estimates for "generalized" atmospheres (including urban, rural, and
industrial) are distinguished from areas close to industrial lead "point"
sources because of significant differences in particle distributions.

     1. <u>General Atmospheres: Adults</u>

     Although lead aerosols in ambient air encompass a broad size range
depending on proximity to sources and meteorological conditions, most urban
and rural airborne lead mass is associated with submicron particles, with a

and absorption of lead particles near lead stationary sources. For example, it is estimated that 15-55% of 5 μm particles by mass deposit in the tracheobronchial region and 8-45% deposit in the alveolar region of mouth-breathing adults (Chan and Lippmann, 1980).

Available data on the size distributions of ambient lead particles in the vicinity of various primary and secondary lead smelters, and battery plants have been compiled (Sledge, 1987). The most reliable size-specific data indicate that near primary lead smelters, approximately 25% of lead particle mass is less than 2.5 μm MMAD (evenly divided between those less than 1 μm and 1-2.5 μm), approximately 20% are between 2.5 and 15 μm, about 40% are between 15-30 μm, and approximately 15% are larger than 30 μm. This size distribution will be assumed for ambient distributions near all point sources and will be combined with deposition data in a way similar to that used by Davidson and Osburn for "generalized" areas.

Because respiratory absorption of deposited lead particles differs depending on particle size (but not chemical form) and region deposited, the Chan and Lippmann (1980) curves with additional data plotted in Figure 2 of the 1986 PM/SO$_x$ Criteria Document Addendum, again appear most useful here for separate estimates of tracheobronchial and alveolar deposition. These curves are presented in terms of either mouth or nose breathing. During the course of a day, inhalation patterns will span a wide range of variation. If averaged however, breathing could typically be characterized as closer to nasal than to mouth breathing for most people (i.e., "normal augmentors"). Based on the estimates of total thoracic deposition by Miller et al. (1986), mouth breathers have between 60-200% higher deposition rates at low ventilation rates (< 30 1/min) than do "normal augmentors". In order to estimate average deposition rates that would typically occur, an attempt is made to estimate deposition curves for typical inhalation patterns from Figure 2 of the 1986 CD Addendum (See Figure A). For extrathoracic or nasopharyngeal deposition, Figures 11-5 and 11-6 of the 1982 PM/SO$_x$ Criteria Document are used in a similar fashion.

The rate of respiratory deposition and subsequent absorption of inhaled lead particles can be calculated for adults breathing ambient air near lead point sources by:

1) Estimate deposition in each of the 3 respiratory tract regions by multiplying the fraction of particles in a size range of the distribution by the average deposition efficiency for that size range read off the Chan and Lippmann curves. For example, about 20% of the lead particle mass distribution is estimated between 2.5 and 15 μm. If average alveolar and tracheobronchial deposition in this size range is estimated to be about 35%, about 7% of the mass in this size range would be calculated as depositing in both of those regions.

2) Multiply each region-specific deposition rate by corresponding absorption estimate, and

3) Sum the individual regions' deposition/absorption rates. Table 1 lists for different particle sizes, region-specific estimated average deposition rates.

Table 1. Estimates of Regional Deposition of Particles Found Near Lead Point Sources

Particle Size Range (µm)	% of Ambient Lead Distribution Near Point Sources	Average Deposition Efficiency		
		Alveolar[1]	T-B[1]	N-P[2]
1. <1.0	12.5	.15	.05	.003
2. 1 - 2.5	12.5	.25	.10	.20
3. 2.5 - 15	20	.20	.25	.40
4. 15 - 30	40	-	.05	.95
5. >30	15	-	-	.95

[1]Read off Figure 2 in 1986 PM/SO_x CD Addendum
[2]Read off Figure 11-5 and 11-6 in 1982 PM/SO_x CD

Applying the above values to the calculation method described above in steps 1-3 yields the following:

Alveolar	Tracheobronchial	Nasopharyngeal
1. .125 x .15 x 100% = 1.9%	.125 x .05 x 40% = 0.25%	.125 x .003 x 40% = .015%
2. .125 x .25 x 100% = 3.1%	.125 x .10 x 40% = 0.5%	.125 x .20 x 40% = 1.0%
3. .20 x .20 x 100% = 4.0%	.20 x .25 x 40% = 2.0%	.20 x .40 x 40% = 3.2%
4. -	.40 x .05 x 40% = 0.8%	.40 x .95 x .40% = 15.2%
5. -	-	.15 x .95 x 40% = 5.7%

Summing the individual values yields a total deposition/absorption rate estimate of 37.7% for adults exposed to ambient lead particles near stationary industrial sources. ·

3. General Atmospheres: Children

Because atmospheric particle size distributions and individual deposition characteristics (e.g., mouth versus oronasal breathers) as well as other factors (e.g., ventilation rates) vary widely, the above discussion may not address potentially important exposure/deposition cases. This is especially true for children, whose respiratory deposition and absorption characteristics have not been studied experimentally. Age-dependent differences in respiratory geometry, air flow conditions, lung clearance mechanisms, and body compartment weight must be applied to make projections from adult data. Mathematical calculations of particle deposition have been developed for children's airways based on morphological measurements of lung geometry and the range of respiratory conditions (e.g., tidal volume, respiratory frequency) in people from birth to adulthood (Xu and Yu, 1986; Phalen et al., 1985).

In general, total deposition and deposition in the head region are estimated to be higher for children than that of adults; the extent of this increase is particle size dependent. However, Xu and Yu calculate that depositions in the tracheobronchial and alveolar region in a child could be larger or smaller, depending upon particle size and the child's age. Because the lead risk assessment is most concerned about 1-3 year olds because of their total exposure patterns and their sensitivity to lead, the curves for 2-year old children in the Xu and Yu paper will be used. (They also present curves for 0.5-year and 8-year olds in relation to adults). For submicron particles, which dominate lead mass in "general" urban/rural atmospheres, the Xu and Yu curves (all for mouth-breathing) indicate that total deposition in the 2-year old is about 1.5 times higher than that of an adult, with the factor for tracheobronchial deposition about 1.2 and alveolar deposition higher in children by 1.3 - 1.6 depending on particle size. The range for lead particle deposition/absorption previously derived for adults in general atmospheres (15-30%) will be multiplied by a factor of 1.5 recognizing that is a fairly crude adjustment that does not explicitly account for factors such as: 1) different deposition rates in children for particles > 1 µm that occur in general atmospheres (the total deposition "age factor" for 1-5 µm particles hovers around 1.5, however); and 2) possible regional differences in absorption rates in children from adults. Nevertheless, this adjustment, albeit simple, appears reasonably appropriate given the available data and a rounded-off range of 25-45% for total respiratory deposition/absorption of inhaled lead particles will be applied to young children living in typical urban/rural atmospheres.

4. Lead Point Sources: Children

As discussed, near point sources there is a greater fraction of large particles in the ambient air that appear to deposit with either greater or less efficiency in children, depending on respiratory region and particle size. For example, .deposition of 10 µm particles in the head (N-P) region is shown to decrease with age after age 2 years (attributed to smaller air passages

in the oropharyngeal region and higher respiratory frequencies of children) and to increase with age after age 2 in the TB and alveolar regions. In contrast, 2 μm particles deposit less efficiently in the Xu and Yu curves with age in the TB region and in the head region, and with progressively greater efficiency in the alveolar region. For each of the 5 segments of the ambient lead distribution near lead point sources given in Table 1, age factors for the different respiratory tract regions can be estimated from Figures 5-9 in Xu and Yu (which only provide values for particles up to 10 μm) and from extrapolations of these curves for the larger particle sizes to adjust the calculations made previously.

Table 2. Adjustments for Regional Deposition Calculations Made in Table 1

Particle Size Range (μm)	Age Factor[1]		
	Alveolar	T-B	N-P
1. < 1.0	1.5	1.5	1.5
2. 1 - 2.5	1.3	1.7	1.5
3. 2.5 - 15	0.5	1.4	2.0
4. 15 - 30	-	0.5	1.0
5. > 30	-	-	1.0

[1]Ratio of deposition fraction in a 2-yr. old's lung (or respiratory tract region) to its counterpart in the adult. Read off curves in Xu and Yu (1986).

Applying these age-factors to the line-by-line calculations made previously on p. 5 yields the following estimates.

Alveolar	Tracheobronchial	Nasopharyngeal
1. 1.9% x 1.5 = 2.9%	0.25% x 1.5 = 0.4%	.015% x 1.5 = .02%
2. 3.1% x 1.3 = 4.0%	0.5% x 1.7 = 0.9%	1.0% x 1.5 = 1.5%
3. 4.0% x 0.5 = 2.0%	2.0% x 1.4 = 2.8%	3.2% x 2.0 = 6.4%
4. -	0.8% x 0.5 = 0.4%	15.2% x 1.0 = 15.2%
5. -	-	5.7% x 1.0 = 5.7%

Summing these individual values yields a total deposition/absorption rate estimate of 42% for young children exposed to ambient lead particles near stationary industrial sources. This is about 4% higher compared to the estimate derived for adults which illustrates the absence of a clear age-related pattern once all particle sizes are accounted for.

Although the estimates described here may contribute a small fraction to the total lead exposure profile in relation to other sources and pathways, it is important that the available data are characterized and used appropriately. We appreciate your time to review this material and any comments you have. Feel free to call (ext. 5282) with comments or questions.

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